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THRESHOLD COINTEGRATION AND GRANGER CAUSALITY BETWEEN CPI AND PPI IN SELECTED COUNTRIES

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Abstract

This paper mainly investigates the threshold cointegration and Granger-causality relationships between the CPI and PPI series in the selected countries for policymakers to effectively control inflation. We first applied the unit root test to ensure the integration order of all the series, and then both the linear Engle-Granger (E-G) and the nonlinear Enders-Siklos (E-S) cointegration tests for comparative analysis. Lastly, Granger causality tests are adopted in the momentum threshold vector error correction model (M-TVECM), which is used to estimate the different speeds of adjustment and explore the causal relationship between CPI and PPI in the selected countries. While the E-G test cannot detect cointegration in almost all countries, the E-S test with higher power when there is asymmetric adjustment, supports the cointegration relationship in Canada, Denmark, Indonesia, Japan, Pakistan, Spain, and Uruguay. The evidence also supports the existence of asymmetric threshold adjustment in all cointegrated systems. In addition, the empirical results indicate that Granger causality in the M-TVECM can be classified into two categories. One kind is about CPI leading to PPI, including Spain only while another kind is about bidirectional causality between CPI and PPI for other countries in the M-TVECM.

Keywords

Threshold Cointegration; CPI; PPI; Momentum Threshold Vector Error Correction Model

JEL classifications: C1, C4

1. Introduction

The Consumer Price Index (CPI) simply measures the average prices for a basket of goods and services commonly purchased by households. CPI is used to determine whether general prices are higher, lower or stable over time, to calculate rate of inflation and to deflating nominal variables to real values. The Producer Price Index (PPI) calculates the change in price of a basket of inputs commonly bought by producers. Similarly, the PPI can be used to deflate the gross domestic product data as well as measuring inflation.

There are two basic approaches to the PPI and CPI causality relationship, which are the supply side and demand side. The production chain view for the supply side argues that these are the changes in PPI that cause CPI, because price changes in the raw materials should pass on to prices of intermediate goods as well as final goods sold to the consumer (Rogers, 1998). Hence, for example, if there is a supply or cost-push shock on fuel, the prices of products related to fuel will be pushed up. Then, changes in the price of fuel should pass through to prices of intermediate products and producer prices for finished products, and lastly to consumer goods. Therefore, shocks to producer prices should ultimately affect consumer prices and consequently PPI causes CPI. The opposite view supported by Colclough and Lange (1982) emphasizes the demand side, according to which changes in the demand for final consumer goods affect the input prices-cost of production. It is because producer prices are normally set as a mark-up over costs of production such as wage costs, which is determined by demand pull. For example, the demand for agricultural raw material depends on prices of food sold to consumers. Changes in the consumer demand for food have an influence on input prices of the food processing industry. Thus, shocks to consumer price should ultimately influence producer prices. Cushing and McGarvey (1990) assumed that demand for primary goods depends on expected future prices of consumer goods, implying that the expected future demand determines producer price. Consequently, changes in CPI lead to PPI. On the other hand, there is possibly no causality between

CPI and PPI series when some items, like services sold to consumers comprising the CPI are not included in the PPI. Therefore, the changes of the two indices are sometimes unrelated so that changes in CPI caused by the changes in prices of service have no impact on PPI.

The evidence of causality is useful for policy makers. If producer prices cause consumer prices, information on producer prices should offer valuable predictive power about consumer prices and then the authorities can identify cost-push shocks that help improve the forecasts of consumer prices inflation (Tiwari, 2012). Similarly, if consumer prices cause producer prices, information on consumer prices should offer valuable predictive power about consumer prices and then authorities can identify demand-pull shocks that are used to help improve the forecasts of producer price inflation.

The consumer and producer price indices are interrelated. Nevertheless, the range of prices included in both indices differs significantly. Indeed, it is common for PPI baskets to include mainly domestically produced goods, while CPI baskets include comprehensive sets of goods and services. To explore the relationship between CPI and PPI, the first thing is to be clear about the differences between these two indices, which mainly focus on several points.

Firstly, the targeted goods and services differ in composition from each other. Compared with CPI, although PPI includes both goods purchased by producers as inputs, as well as goods bought by consumers from retail sellers and producers directly, the prices for services are excluded from PPI. Furthermore, the effects of taxes should not be neglected. This is because sales and taxes, which are not included in the revenue of the producer's returns, actually are reflected in CPI, as they are necessary expenditures for the consumers. As a result, when there is a change in the tax rate on cigarettes or alcoholic beverages, CPI can move without any change in the PPI. Further, the differences of the two indices can show different aspects of the economy. Researchers can track the real growth of output of economy according to the producer price index after adjusting inflated revenue sources, whereas the consumer price index can be applied to calculate changes in the cost of living by adjusting income and expenditure streams.

Consequently, the so-called pass-through theory or supply-side approach, which implies changes in prices of crude materials should pass through to prices of intermediate goods and ultimately to consumer prices (Clark, 1995), may not be totally realized because of the existence of different components. Although some may assume that the price change in a particular part of PPI can directly and finally be transferred into the counterpart of CPI, whether there is a pass-through of price change is hard to measure, so is the extent of validity of the pass through. A similar argument can be applied to the demand-pull approach.

The main purpose of the paper is to study the relationships between CPI and PPI series with asymmetric adjustments in several selected countries around the world so that we can provide more international evidence of the CPI-PPI relationship and causality. Given the literature that explores the threshold adjustment in the system of CPI and PPI (e.g., Esteve et al., 2006), we adopt the momentum threshold cointegration tests of Enders and Siklos (2001) with asymmetric error-correction process for analysis. This method has been neglected in previous literature for the analysis of the CPI-PPI system. The power of this method for cointegration test is much higher than traditional cointegration tests with symmetric adjustment if the true adjustment process is asymmetric. In addition, the momentum threshold cointegration method allows the model to display differing speeds of autoregressive decay depending upon whether the *changes* in discrepancies from equilibrium are climbing up or falling (Enders and Siklos, 2001). This nonlinear asymmetric adjustment is helpful to smooth out the large fluctuations in the series in the paper. Therefore, authorities might take strong measures to offset shocks to the PPI or CPI if such shocks are sufficiently strong to lead the producer or consumer inflation to deviate further from the equilibrium. This may reflect the asymmetric inflation control measures by authorities. Lastly, in order to explore the causal relationship between the CPI and the PPI in all the selected countries, the Granger-causality test is conducted in a momentum threshold vector error-correction model.

We organize the rest of the paper as follows. Section 2 outlines the methodology, Section 3 contains the data description, Section 4 reports the empirical results, and Section 5 concludes.

2. Literature Review

Colclough and Lange (1982) argued that consumer prices should affect producer prices, because the demand for final goods and services determines the demand inputs. Based on the framework, the cost of production reflects the opportunity cost of resources and intermediate materials, which in turn also reflects the demand for final goods and services. Cushing and McGarvey (1990) suggested that consumer prices depend on the producer price of the home good, the price of the imported good, the exchange rate, level of indirect taxes, the marginal cost of retail production, and a possible markup. Later, Rogers (1998) supported the production chain view for the supply side and argued that it is the changes in PPI that cause CPI, because price changes in the raw materials should pass on to prices of intermediate goods as well as final goods sold to the consumer.

Compared with the traditional method of error correction model (ECM), which describes the response of the variables to the deviations from the equilibrium, Balke and Fomby (1997) suggested an approach that combines nonlinearity and cointegration, which we call threshold cointegration. The tendency to move towards the long-run equilibrium does not happen every time. Therefore, there could be discontinuous adjustment. Enders and Siklos (2001) suggested an alternative threshold specification that permits asymmetric adjustment in the error-correction term and provides relevant critical values to test for threshold cointegration. Hansen and Seo (2002) proposed an approach to test the existence of a threshold effect in the long-run adjustment process in an error correction model. However, they did not provide proper tests for threshold cointegration. Many previous papers have done empirical studies to examine the cointegration and causal relationship between CPI and PPI in many countries using different kinds of methods. The linear cointegration relationship has not been found between CPI and PPI in Australia from 1969q3 to 2010q4 (Tiwari, 2012). There was no cointegration between PPI and CPI in Turkey using data from 1987:01 to 2004:08 with both Engle-Granger (1987) and Johansen (1988) tests (Akdi et al., 2006). The CPI caused PPI in the USA (Colclough and Lange, 1982) with Sims and Granger causality tests, whereas Jones (1986) found bidirectional causality between PPI and CPI in the US. Caporale et al. (2002) argued that there was unidirectional causality running from PPI to CPI in France and Denmark, causality was bidirectional in Italy, and no causality was found in Canada using the Toda and Yamamoto (1995) approach from 1976:01 to 1999: 04.

3. Methodology

To investigate the cointegration between CPI and PPI series in these selected countries, we will adopt the Dickey-Fuller generalized-least-squares (DF-GLS) test (Elliott, et al., 1996) to test for the stationarity of the CPI and PPI series, which utilizes the null hypothesis of having a unit root against the alternative of stationary series. The lag lengths in the fitted regressions depend on the Schwarz criterion (SC). If all series are integrated of order 1, denoted by **I**(1), we proceed to cointegration tests.

Next, the traditional Engle-Granger (1987) cointegration methodology is used to test for the long-run equilibrium relationship for the series of CPI and PPI, with the null hypothesis that there is no cointegration against the alternative of cointegration with symmetric adjustment. We will first adopt ordinary least squares (OLS) to estimate the long-run equilibrium relationship as:

$$\mathrm{y_t} = \mathrm{a} + \mathrm{b}\mathrm{x_t} + \mu_\mathrm{t}, \tag{1}$$

where a and b are the estimated parameters, $\mathrm{y_t}$ and $\mathrm{x_t}$ are the price indices under study, and μ_t is the disturbance term that may be serially correlated.

Then, Dickey-Fuller regression is constructed for μ_t and we focus on the OLS estimate of ρ in the regression equation:

$$\hat{\mu}_t = \rho\hat{\mu}_{t-1} + \sum_{i=1}^{k}\delta_\mathrm{i}\Delta\hat{\mu}_{t-i} + \nu_t, \tag{2}$$

where δ_i is the regression coefficients of lagged differenced terms and ν_t is a white noise disturbance. If the regression residual μ_t is stationary and then it is significant to reject the null hypothesis of no cointegration by using the t and z statistics on ρ (Engle and Granger, 1987), there is a long-run equilibrium between CPI and PPI series, implying that they are cointegrated with symmetric adjustment.

However, the point is that the traditional cointegration tests overlook the situation of asymmetric adjustment. For example, the Engle-Granger tests only account for symmetric cointegration, which is neither complete nor accurate. As we mentioned previously, there is evidence of asymmetric adjustments between CPI and PPI series in literature. Therefore, we need to further test for long-term equilibrium with the existence of asymmetric adjustment. The so-called threshold autoregressive (TAR) model (Tong, 1983) is provided to allow the degree of autoregressive decay depending upon the state of the threshold variable. Enders and Siklos (2001) made a specification of asymmetric threshold autoregressive model to address this problem. The TAR model for μ_t is:

$$\Delta\hat{\mu}_\mathrm{t} = \rho_1\mathrm{I_t}\hat{\mu}_\mathrm{t-1} + \rho_2(1-\mathrm{I_t})\hat{\mu}_\mathrm{t-1} + \nu_\mathrm{t} \tag{3}$$

$$\text{where } \mathrm{I_t} = \begin{cases} 1 & \text{if } \mu_\mathrm{t\text{-}1} \geq \tau \\ 0 & \text{if } \mu_\mathrm{t\text{-}1} < \tau \end{cases} \tag{4}$$

$\mathrm{I_t}$ is called the Heaviside indicator, ρ_1 and ρ_2 represent the speed of adjustment coefficients in two regimes, τ is the value of threshold, and ν_t is independent of μ_j (j<t). The consistently estimated value of τ can be searched from the fitted model (3) such that the sum of squared errors of the fitted model is minimized.

Adjustment is symmetric if $\rho_1 = \rho_2$ so that the Engle-Granger test is just a special case of the TAR model. From (4), the TAR model allows μ_t to display differing amounts of autoregressive decay depending on whether its previous value μ_{t-1} is greater or smaller than the threshold value.

However, the Equation (3) may not be sufficient to capture the dynamic adjustment of μ_t toward long-run equilibrium value. Enders and Siklos (2001) show that the different amounts of autoregressive decay can depend on whether the previous *change* in μ_{t-1} is climbing up or falling, and then suggests the momentum threshold autoregressive (M-TAR) model:

$$\Delta \hat{\mu}_t = \rho_1 M_t \hat{\mu}_{t-1} + \rho_2 (1 - M_t) \hat{\mu}_{t-1} + \sum_{i=1}^{k} \delta_i \Delta \hat{\mu}_{t-i} + \nu_t, \tag{5}$$

$$\text{where } M_t = \begin{cases} 1 & \text{if } \Delta\mu_{t-1} \geq \tau \\ 0 & \text{if } \Delta\mu_{t-1} < \tau \end{cases} \tag{6}$$

M_t is also represented as the Heaviside indicator. M-TAR adjustment can be especially useful when policy makers are considered as attempting to mitigate any large *changes* in series under study. The main purpose of this paper is to study the relationship between CPI and PPI series, when the inflation rate is calculated as the change in the natural log of price indices. The government authorities might tend to take measures to offset shocks to the CPI-PPI relationship if such shocks are considered to induce an increase in inflationary pressures caused by the widening of the discrepancies in the CPI-PPI relationship. The M-TAR model constructed using (6) shows different speeds of decay depending upon increasing or decreasing discrepancies from equilibrium in a previous period $\Delta\mu_{t-1}$, is then more appropriate than the TAR model constructed using (4) in this paper. Hence, we apply the M-TAR model only in the following part of paper.

As suggested by Enders and Siklos (2001), there are two sequential steps of testing for threshold cointegration: one is to test for linear cointegration, and the other is to test for nonlinear adjustment process. The first step is the linear cointegration test, which is to test the null hypothesis of $\rho_1 = \rho_2 = 0$ using the F statistics. Because F statistic is non-standard under the null, the corresponding critical values are obtained from simulation and can be found in Table 5 of Enders and Siklos (2001).[1] The F statistic is denoted by Φ(M). If the Φ(M) statistic cannot reject the null of non-cointegration, we stop and exclude the series under study out of the subsequent analysis. If the Φ(M) statistic rejects the null of non-cointegration, we implement the second step of testing for the null hypothesis of whether there is symmetric adjustment, that is $\rho_1 = \rho_2$ with the standard F-statistic. That is to say, the standard F statistic is used to test the null hypothesis of symmetric adjustment behavior against the alternative one about the existence of asymmetric adjustment, depending on whether $\Delta\mu_t \geq \text{or} < \tau$. If it can significantly reject the null hypothesis of $\rho_1 = \rho_2$, the existence of asymmetric adjustment can be supported.

Subsequently, the causal relationship of CPI and PPI series should be explored for cointegrated systems. Unlike the conventional Granger causality test, which is applied to check the linear causal relationship between series in vector autoregressive (VAR) model, we combine both the vector error correction model (VECM) and the M-TAR model into the momentum threshold vector error correction model (M-TVECM), which is used to conduct the nonlinear Granger causality test. The M-TVECM is specified as follows:

$$\Delta CPI_t = \alpha_0 + M_t \rho_{1c} \hat{\mu}_{t-1} + (1 - M_t) \rho_{2c} \hat{\mu}_{t-1} + \sum_{j=1}^{L} \alpha_{1j} \Delta CPI_{t-j} + \sum_{j=1}^{L} \alpha_{2j} \Delta PPI_{t-j} + \varepsilon_{1t} \tag{7}$$

$$\Delta PPI_t = \beta_0 + M_t \rho_{1p} \hat{\mu}_{t-1} + (1 - M_t) \rho_{2p} \hat{\mu}_{t-1} + \sum_{j=1}^{L} \beta_{1j} \Delta CPPI_{t-j} + \sum_{j=1}^{L} \beta_{2j} \Delta PPI_{t-j} + \varepsilon_{2t} \tag{8}$$

where α_0 and β_0 are intercepts, $\rho_{1c}, \rho_{2c}, \rho_{1p}$ and ρ_{2p}, are the estimated asymmetric adjustment coefficients. The optimal lag order is L chosen based on the model criterion and, ε_{1t} and ε_{2t} are the error terms that are assumed to be white-noise disturbances.

The Granger causality is used to test the direction of causal relationship from PPI to CPI in (7) under the null hypothesis of $\rho_{1c} = \rho_{2c} = \alpha_{2j} = 0$ for all j with the standard Wald statistic. The inclusion of $\rho_{1c} = \rho_{2c} = 0$ in

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[1] The EG and ES models can be estimated by GLS. The critical values can be found in Woo and Lee (2015).

the Granger causality test is due to the inclusion of PPI series in the previous period’s disequilibrium μ_{t-1} (Koop, 2005). If the statistic can significantly reject the null hypothesis that PPI does not Granger-cause CPI, then PPI can Granger-cause CPI. On the contrary, the direction from CPI to PPI can be tested in the Granger causality test in (8) under the null hypothesis of $\rho_{1p} = \rho_{2p} = \beta_{1j} = 0$, for all j. Likewise, the inclusion of $\rho_{1p} = \rho_{2p} = 0$ in the Granger causality test is due to the inclusion of CPI series in the previous period’s disequilibrium μ_{t-1}. If the standard Wald statistic can significantly reject the null hypothesis that CPI does not Granger-cause PPI, then the result that CPI can Granger-cause PPI can be concluded.

4. Data

All the monthly data of both CPI and PPI series are obtained from the IMF International Financial Statistics. The 10 selected countries are: Australia, Canada, Denmark, Indonesia, Japan, Norway, Pakistan, Spain, Uruguay, and the US. The sample periods run from 1980:01 to 2012:03, except that data for Japan are collected from 1974:01 to 2012:03, for Pakistan and Spain from 1981:01 to 2012:03, and for Denmark and Uruguay from 1985:01-2012:03. All price indices are taken in natural logarithm and seasonally adjusted using the X12 method.

5. Empirical results

Unit root test

Before conducting the cointegration tests, We apply the Dickey-Fuller generalized least squares (DF-GLS) test to examine the null hypothesis of having a unit root against the alternative of stationarity for both CPI and PPI series in all sampled countries. As seen from the results in Table 1, the DF-GLS tests cannot reject the null of a unit root for all series in level. However, they can significantly reject the null when all the series are in the first difference. As a result, We conclude that the series are all **I**(1), which is the premise of cointegration.

Country	**CPI**				**PPI**			
	level	**Lag**	**First difference**	**lag**	**Level**	**Lag**	**First difference**	**Lag**
Australia	-0.642	7	-3.995***	6	-1.248	2	-10.433***	1
Canada	-0.320	5	-4.354***	4	-0.447	1	-12.647***	0
Denmark	-0.396	0	-15.411***	0	-1.323	2	-5.156***	3
Indonesia	-2.430	4	-4.255***	3	-1.451	0	-15.775***	0
Japan	-0.808	12	-4.016***	11	-0.591	1	-4.632***	0
Norway	-0.551	8	-13.013***	0	-0.609	0	-18.623***	0
Spain	-0.814	9	-3.380**	8	-0.723	3	-5.135***	2
Pakistan	-0.760	3	-3.982***	4	-1.193	2	-9.452***	1
Uruguay	-0.842	12	-3.408**	11	-0.492	12	-3.934***	11
USA	-0.390	3	-4.170***	3	-1.773	1	-4.980***	2

Table1 DF-GLS unit root test

Notes:
A constant and a linear trend are included in the test regression.
The choice of lags is based on Schwarz Criterion (SC).
The critical values are -3.4783, -2.8926 and -2.5760 at the 1%, 5% and 10% level, respectively.
Asterisk (***), (**) and (*) denote the statistical significance at the 1%, 5% and 10% level, respectively.

Engle-Granger cointegration test

After the unit root tests, we implement the Engle-Granger cointegration test. The estimated coefficients (b) of Equation (1) and the cointegration test results are presented in Table 2. The Engle-Granger t statistics and z statistics are insignificant and cannot reject the null hypothesis of no long-run cointegration relationship for all cases excepting the cases of Indonesia and Pakistan where the null hypothesis can be rejected at the 10% and 1% significance level, respectively. As for Denmark, t statistic can reject the null, but z statistic cannot. Generally, the evidence of the Engle-Granger cointegration test statistics is not in favor of cointegration with symmetric adjustment process.

Country	b	t-stat	p-value	z-stat	p-value	lag	SC
Australia	1.755	-1.011	0.8997	-2.722	0.8943	2	-6.061
Canada	1.282	-2.122	0.4650	-8.984	0.4241	2	-7.132
Denmark	1.202	-3.827**	0.0137	-15.314	0.1360	2	-7.397

Indonesia	0.889	-3.100*	0.0907	-19.101*	0.0640	0	-4.779
Japan	0.805	-2.452	0.3020	-3.338	0.8560	3	-8.355
Norway	0.746	-1.102	0.8814	-1.821	0.9390	0	-5.755
Pakistan	0.913	-4.223***	0.0038	-35.855***	0.0015	1	-7.008
Spain	1.430	-0.789	0.9337	-2.580	0.9023	3	-7.668
Uruguay	1.057	-1.085	0.8851	-3.495	0.8451	12	-3.956
USA	1.294	-1.983	0.5373	-6.672	0.5955	1	-6.300

Table 2. Enders-Granger cointegration test

Notes:
CPI is the dependent variable in the equation.
The lag length is chosen based on Schwarz Criterion (SC).
P-values are based on the MacKinnon (1996).
Asterisk (***), (**) and (*) denote the statistical significance at the 1%, 5% and 10% level, respectively.

Enders-Siklos momentum threshold cointegration test

The Engle-Granger test previously could not find any cointegration relationship between CPI and PPI series for almost all countries, because the Engle-Granger test overlooks the existence of asymmetric adjustments and then may lead to misspecification. To allow for the possibility of nonlinearity in the adjustment process, we apply the Φ(M) statistic to re-examine the cointegration relationship between CPI and PPI series in M-TAR models, and the empirical results are then reported in Table 3.

Country	Φ(M): $\rho_1 = \rho_2 = 0$	lag	F-test: $\rho_1 = \rho_2$	ρ_1	ρ_2	τ
Australia	2.006	2	___	___	___	___
Canada	5.978*	2	7.378***	0.0044	-0.0350	-0.0003
Denmark	10.201***	3	7.537***	-0.0357	-0.0024	0.0013
Indonesia	8.032**	2	6.941***	-0.1805	-0.0355	0.0142
Japan	9.523***	1	6.721***	0.0009	-0.0058	0.0033
Norway	3.043	1	___	___	___	___
Spain	8.983***	2	16.796***	-0.0539	0.0016	0.0057
Pakistan	16.386***	2	8.391***	0.0005	-0.2012	0.0046
Uruguay	6.890**	8	13.415***	0.0005	-0.2012	-0.0236
USA	2.000	8	___	___	___	___

Table 3: Enders-Siklos M-TAR cointegration test

Notes:
Critical values of the Φ(M) tests are based on Table 5 of Enders and Siklos (2001).
Critical values of the standard F statistic are 6.635, 3.8415 and 2.70554, at 1%, 5% and 10% level, respectively.
Asterisk (***), (**) and (*) denote the statistical significance at the 1%, 5% and 10% level, respectively.

From Table 3, the Φ(M) statistics can reject the null hypothesis of non-cointegration ($\rho_1 = \rho_2 = 0$) for 7 countries, which are Canada, Denmark, Indonesia, Japan, Spain, Pakistan, and Uruguay, indicating that there is long-run equilibrium in these countries. The cointegrating parameters (b) of these countries can be found in Table 2 and the parameters are found to be deviating from unity. For example, the value of b for Spain is 1.43. The null of non-cointegration for 3 other countries - Australia, Norway, and the USA - cannot be rejected and as such these 3 countries will be dropped from the analysis. Subsequently, we implement the second step of the Enders-Siklos test, examining the null of linearity $\rho_1 = \rho_2$ for the cointegrated cases using the standard F statistic. The empirical evidence demonstrates the existence of threshold cointegration with asymmetric adjustment $\rho_1 \neq \rho_2$ in the M-TAR models of these 7 countries. The estimated threshold variables are also reported in Table 3.

Taking Canada as an example, we find that the estimated Φ(M) statistic of cointegration test (5.978) is significant at the 10% level, and the estimated F-statistic of nonlinearity test (7.378) is significant at the 1% level. As a result, the null hypotheses of both the non-cointegration of $\rho_1 = \rho_2 = 0$ and the symmetric adjustment of $\rho_1 = \rho_2$ are rejected, implying there is threshold cointegration with asymmetric adjustment in Canada.

Compared with the Engle-Granger test, the Enders-Siklos M-TAR cointegration test enjoys higher power to detect the cointegration relationship, allowing for asymmetric error-correcting adjustments. We now proceed to estimate the M-TVECM to exploit the asymmetric adjustment process in the bivariate system.

Estimation of the momentum threshold vector error correction model (M-TVECM)

The estimation of the M-TVECM in the form of (7) and (8) is done by the OLS method. The adjustment coefficients, $\rho_{1c}, \rho_{2c}, \rho_{1p}$ and ρ_{2p}, of the error-correction terms in the M-TVECM are presented in Table 4. The results show the asymmetry of the adjustment processes in the M-TVECM. We find that all the significant coefficients are of correct sign. For Canada, Denmark, Spain, and Uruguay, only one adjustment coefficient in either equation of CPI or PPI is significant. From Tables 3 and 4, the adjustment coefficient in the equation of PPI in Canada is significant only when $\Delta\mu_{t-1} < -0.0003$. In Denmark, the adjustment coefficient in the equation of CPI is significant only when $\Delta\mu_{t-1} > 0.0013$. In Spain, the adjustment coefficient in the equation of PPI is significant only when $\Delta\mu_{t-1} \geq 0.0057$. In Uruguay, the adjustment coefficient in the equation of CPI is significant only when $\Delta\mu_{t-1} < -0.0236$. Moreover, for Indonesia, all adjustment coefficients in the equation of PPI are significant and it is found that the increasing discrepancies from long-term equilibrium (such that $\Delta\mu_{t-1} \geq 0.0142$), are eliminated much quicker than the decreasing discrepancies (such that $\Delta\mu_{t-1} < 0.0142$). For Japan, all adjustment coefficients in the equation of CPI are significant and it is found that the increasing discrepancies from long-term equilibrium (such that $\Delta\mu_{t-1} \geq 0.0033$), are eliminated slightly faster than the decreasing discrepancies. Also, for Pakistan, all adjustment coefficients in the equation of PPI are significant and it is found that the increasing discrepancies from long-term equilibrium (such that $\Delta\mu_{t-1} \geq 0.0046$), are eliminated much quicker than the decreasing discrepancies. Also, only the adjustment coefficient in the equation of CPI in the regime of increasing discrepancies from equilibrium is significant. In general, discrepancies from equilibrium resulting from increases in consumer prices would be eliminated quicker than increase in producer prices. It may reflect the stronger measures to control consumer price inflation than producer price inflation.

Besides the asymmetry, it is found that the price indices adjust in response to disequilibrium when at least one corresponding adjustment coefficient is significant (Granger, 1988). The complete picture of Granger causality between the price indices can be shown using the Granger causality tests in the M-TVECM.

Country	Dependent Variable	Adjustment coefficients		Q(1)	Q(2)
		ρ_{1c}, ρ_{1p}	ρ_{2c}, ρ_{2p}		
Canada	CPI	-0.0033 （0.0046）	-0.0063 （0.0045）	0.341 [0.987]	1.572 [0.992]
	PPI	-0.0045 （0.0088）	0.0219** （0.0087）		
Denmark	CPI	-0.0640** (0.0284)	0.0115 (0.0269)	0.296 [0.990]	0.551 [0.999]
	PPI	-0.0924 (0.0620)	0.0398 (0.0586)		
Indonesia	CPI	0.0246 （0.0227）	-0.0100 （0.0070）	0.123 [0.998]	0.641 [1.000]
	PPI	0.1817*** （0.0688）	0.0131 （0.0210）		
Japan	CPI	-0.0139*** （0.0023）	-0.0101*** （0.0014）	1.532 [0.821]	3.449 [0.903]
	PPI	-0.0031 （0.0031）	-0.0024 （0.0016）		
Spain	CPI	-0.0047 (0.0068)	-0.0009 (0.0024)	1.022 [0.906]	1.806 [0.986]
	PPI	0.0313*** (0.0090)	0.0003 （0.0031）		
Pakistan	CPI	-0.0534** （0.02690）	-0.0238 （0.0171）	0.107 [0.998]	0.612 [1.000]
	PPI	0.1223*** （0.0433）	0.0523* （0.0275）		

Uruguay	CPI	0.0096 （0.0097）	-0.1952*** （0.0382）	2.201 [0.699]	9.415 [0.309]
	PPI	0.0059 （0.0106）	0.0640 （0.0397）		

Table 4: Estimation of M-TVECM

Notes:
Q(1) and Q(2) represent the autocorrelation Q-statistics of 1 lag and 2 lags, respectively.
Standard error is shown in parentheses.
The p-value are presented in the squared brackets.
Asterisk (***), (**) and (*) denote the statistical significance at the 1%, 5% and 10% level, respectively.

Granger causality test in M-TVECM

From the results presented in Table 5, we can see from the results that the null hypothesis of no Granger causality from PPI to CPI can be rejected, but the null hypothesis of no Granger causality from CPI to PPI cannot be rejected in Spain, implying that there is a unidirectional causality from CPI to PPI. Consequently, the empirical evidence can demonstrate the demand side approach and it can help policy makers in these countries predict future producer inflation rate. Therefore, the current inflation in Spain should be demand-led, and ease monetary conditions are the important reasons to promote flourishing demand. Then, inflation control should start with excess liquidity, and then guide the money supply into the production area.

The second case is that both the null hypothesis of no Granger causality from PPI to CPI and the null hypothesis of no Granger causality from CPI to PPI can be rejected in the rest of countries - Canada, Denmark, Indonesia, Japan, Pakistan and Uruguay - implying the bidirectional causality between CPI and PPI. Consequently, the empirical evidence can support both the supply and demand side approaches, thus policy makers can use both the CPI and PPI to make future inflation rate predictions. Consequently, inflation is caused by both the supply and demand sides, so policymakers should control inflation by focusing on both sides. Apart from controlling the excess liquidity, input prices should also be under control. The manufacturing sectors use domestic or imported materials as inputs. The input prices depend not only on domestic demand and supply, but also on their imports. The latter depends on the prices of the imported goods, the nominal exchange rate, the level of indirect taxes, the marginal cost of production, and interest rates. Therefore, it is important to have good control of all these factors.

Country	Null Hypothesis	Wald Statistics	p-value	Direction of causality
Canada	PPI does not Granger cause CPI	13.955**	0.0301	CPI↔PPI
	CPI does not Granger cause PPI	13.135**	0.0409	
Denmark	PPI does not Granger cause CPI	17.832***	0.0013	CPI↔PPI
	CPI does not Granger cause PPI	15.453***	0.0038	
Indonesia	PPI does not Granger cause CPI	73.479***	0.0000	CPI↔PPI
	CPI does not Granger cause PPI	20.844***	0.0020	
Japan	PPI does not Granger cause CPI	82.359***	0.0000	CPI↔PPI
	CPI does not Granger cause PPI	18.885***	0.0044	
Pakistan	PPI does not Granger cause CPI	14.487**	0.0246	CPI↔PPI
	CPI does not Granger cause PPI	14.337**	0.0261	
Spain	PPI does not Granger cause CPI	9.045	0.1710	CPI→PPI
	CPI does not Granger cause PPI	29.550***	0.0000	
Uruguay	PPI does not Granger cause CPI	672.552***	0.0073	CPI↔PPI
	CPI does not Granger cause PPI	155.519***	0.0000	

Table 5 Nonlinear Granger causality test

Notes: Asterisk (***), (**) and (*) denote the statistical significance at the 1%, 5% and 10% level, respectively.

6. Conclusion

This paper explores the cointegration relationship between CPI and PPI in selected countries around the world, such as Australia, Indonesia, Uruguay and so on, and both Engle-Granger (1987) test and Enders-Siklos (2001) asymmetric cointegration test in M-TAR model have been adopted. In addition, this paper also tests for Granger causality in M-TVECM.

The results suggest that the power of the Enders-Siklos test is higher than Engle-Granger test because the cointegration relationship in Canada, Japan, Spain, and Uruguay has not been demonstrated with the Engle-Granger test, but was supported by the Enders-Siklos test, for the latter takes asymmetric adjustments into consideration.

The empirical results obtained from the Granger causality between CPI and PPI in the selected countries can be classified into two categories: one is about PPI leading to CPI, including Spain; another is the bidirectional causality, including Canada, Denmark, Indonesia, Japan, Pakistan, and Uruguay, and the corresponding policies that have been suggested in the paper. The directions of the causal relationship between the CPI and the PPI are important. Not only because it allows policy makers to predict future inflation, but it also helps policy makers to be well prepared to avoid, or at least mitigate, the negative consequences of inflation. The results can help policy makers to rely more on the link between CPI and PPI for inflation control and prediction.

When it relates to the situation where CPI causes PPI, we can term this as demand-pull inflation. To reduce the inflationary pressures, some actions, such as contractionary monetary and fiscal policies, should be taken to reduce the growth of aggregate demand. The central bank could increase interest rates to control excess liquidity and the growth of money supply. Higher rates make borrowing more expensive and saving more attractive. This should lead to lower growth in consumer spending and investment. Furthermore, a higher interest rate also leads to a higher exchange rate, which not only makes imports cheaper, but also reduces demand for exports, increasing the incentive for exporters to cut costs. For government, taxes can be increased to reduce the demand in the economy.

In the situation where PPI causes CPI, we can term this as cost-push inflation, and input prices would become the focus of the policy. On one hand, controlling wage growth can be efficient to help moderate this kind of inflation, because lower wage growth helps to reduce cost-push inflation. More flexible labour markets may help reduce inflationary pressure. On the other hand, other policies like controlling interest rate, tax rate, nominal exchange rate and so on, could be applied to control input price level.

Finally, when the CPI and PPI are in a mutual cause-effect relation, policies should reflect a combination of both sides.

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